EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF MODES OF NITRIDING ON THE DAMPING ABILITY OF 45 STEEL

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By using numerical methods, for specimens of 45 steel subjected to various modes of nitriding in a hydrogen-free atmosphere, we determine the parameters of the process of nitriding guaranteeing the maximum possible level of their damping ability. The results of testing control specimens of 45 steel subjected to the optimal procedure of nitriding revealed practically complete coincidence between the numerical and experimental values of the decrement of vibrations whose level was higher than for nonnitrided specimens by a factor of 3.4.

In [1], we studied the damping properties of specimens made of 45 steel and VT1-0 titanium alloy subjected to ionic nitriding in a hydrogen-free atmosphere. We discovered significant variations of the characteristic of damping ability (decrement of vibrations) for tested specimens depending on the parameters of the process of nitriding. We suggested a computational method for determining the parameters of the process of nitriding guaranteeing the maximum possible level of the decrement of vibrations even for relatively small changes in the applied modes and, hence, for a relatively small collection of specimens.

The present work is devoted to the experimental investigation of the applicability of the indicated computational method for the determination of the most advantageous modes of nitriding from the viewpoint of the damping ability of materials.

The tests were carried out on specimens of 45 steel manufactured from the same batch of the metal and subjected to the same mode of preliminary heat treatment.

The decrement of vibrations was determined by analyzing free damped vibrations in specimens with prismatic working section under pure bending according to the procedure described in [2].

In Fig. 1, we present the dependences of the decrement of vibrations on the amplitude of stresses for specimens of 45 steel in the as-received state and after nitriding.

It is easy to see that nitriding leads to a noticeable increase in the decrement of vibrations of specimens (by a factor of 1.2–2.3) and that the magnitude of these changes essentially depends on the mode of nitriding. In the process of nitriding, we varied its parameters within the following ranges: ambient pressure $P = 80$–$400$ Pa, temperature $T = 753$–$873$ K, duration of process $\tau = 20$–$240$ min, and concentration of argon in its mixture with nitrogen $\text{Ar} = 0$–$76$ vol. %.

The number of curves in Fig. 1 is smaller than the number of tested specimens nitrided in various modes because the data obtained for some of these specimens were very close to each other. However, in determining the optimal mode of nitriding (from the viewpoint of the maximum damping ability), we took into account the entire collection of accumulated data.

According to the procedure described in [1], we deduced regression equations by using the experimental values of the decrement of vibrations for three values of the amplitude of cyclic stresses (50, 75, and 100 MPa) and computed values of the regression coefficients. The graphic representation of the final regression equations (they are not presented here for the sake of brevity) reveals the presence of extrema in the curves of the parameters of the process of nitriding and, hence, it was possible to find their optimal values: $P = 160$ Pa, $T = 808$ K, $\tau = 130$ min, and $\text{Ar} = 38$ vol. %.


0039–2316/97/2905–0517$18.00 ©1998 Plenum Publishing Corporation
Fig. 1. Dependences of the decrement of vibrations on the amplitude of stresses for specimens of 45 steel (solid lines correspond to nitriding in various modes and the dashed line corresponds to the as-received state).

Fig. 2. Decrement of vibrations vs the amplitude of stresses for 45 steel: (1) experimental data for specimens nitrided in the optimal mode, (2) numerical values of the decrement of vibrations (the dashed line corresponds to nonnitrided specimens).

For the indicated parameters of nitriding, the computed values of the decrement of vibrations for specimens of 45 steel are 0.55%, 0.57%, and 0.66% if the amplitude of stresses is equal to 50, 75, and 100 MPa, respectively.

The check lot of specimens of 45 steel was subjected to nitriding in the mode characterized by the indicated optimal values of the parameters. After this, we measured the experimental values of the decrement of vibrations of these specimens within the same range of amplitudes of stresses as for all other specimens.

The experimental and numerical dependences of the decrement of vibrations $\delta$ on the amplitude of stresses $\sigma$ are depicted in Fig. 2. The dashed-dotted line is drawn according to the numerical values of the decrement of vibrations for a more convenient presentation of its dependence on the amplitude of stresses.

The analysis of our results demonstrates, first of all, that the level of the decrement of vibrations for check specimens nitrided in the optimal mode is higher than for all other tested specimens. Its mean value is as high as 0.47–0.66% depending on the amplitude of stresses. The deviations of individual values of the decrement of vibrations from its mean value never exceed 10%. The experimentally measured mean level of the decrement of vibrations for check specimens is at least 3.2–3.4 times as large as for specimens which were not subjected to nitriding.